DOCUMENT RESUME

ED 448 166		TM 032 081

AUTHOR	Schreiber, James B.
TITLE	Scoring above the International Average: A Logistic Regression Model of the TIMSS Advanced Mathematics Exam.
PUB DATE	2000-10-00
NOTE	20p.; Paper presented at the Annual Meeting of the Mid-Western Educational Research Association (Chicago, IL, October 25-28, 2000).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Academic Achievement; *High School Students; High Schools; *International Studies; *Mathematics Achievement; Mathematics Tests; Parent Background; Physics; Science Tests; *Scores; Student Attitudes; *Test Results
IDENTIFIERS	*Mean (Statistics); *Third International Mathematics and Science Study

ABSTRACT

The student variables associated with scoring above the international mean on the Third International Mathematics and Science Study (TIMSS) were studied in a group of U.S. students who took advanced mathematics or advanced mathematics and physics. The total sample was 2,349, with 1,158 females and 1,191 males. Formal parent education level and gender were significantly associated with scoring above the international mean, showing that this traditionally observed disparity still exists. Students enrolled in both advanced mathematics and advanced physics were three times as likely to score above the international average as students enrolled only in advanced mathematics. Results show that the more a student believed that natural talent was the key to mathematics success, the more likely the student scored above the international average, and the less a student believed that hard work was the key to mathematics success, the more likely the student scored over the international average. In addition, scoring above the international average was associated with more time studying and less time in nonacademic activities. The most disturbing finding from the study may be that only 26% of the most advanced students scored above the international mean, suggesting that the most advanced students in the Untied States are not reaching the level one would expect. An appendix lists the variables considered. (Contains 39 references.) (SLD)

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Scoring Above the International Average: A Logistic Regression Model of the TIMSS Advanced Mathematics Exam

James B. Schreiber
Southern Illinois University-Carbondale

Presented at the Mid-Western Educational Research Association annual meeting, Chicago, IL October 2000

James B. Schreiber
Department of Educational Psychology and Special Education
Mailcode 4618
Carbondale, IL 62901
Bloomington, IN 47408
Current E-mail: jschreib@siu.edu

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Background

The intense concern over the mathematics achievement levels of United States elementary and high-school students can be seen through the number of articles published (Baker, 1993a, 1993b; Bracey, 1991, 1992, 1993; Freudenthal, 1975, Rotberg, 1990; Stedman, 1994a, 1994b). A great deal of debate has centered on the fact that the U.S. scored lower than many countries on most of the assessments. Very little discussion has focused on U.S. high school seniors and on the factors that are associated with scoring above the international mean. The questions which motivate this study are: What student variables are associated with scoring above the international mean on the TIMSS advanced mathematics test? How much of an impact do these variables make for those students who scored above the international average?

Theoretical Framework

Over the past few decades a great deal of research has been conducted on the student level factors that impact mathematics achievement. The positive relationship between attitude (ATT) and achievement (ACH) has long been observed (Ethington & Wolfe, 1984, 1986; Lester, Garafalo, & Kroll, 1989; Ma, 1997; Suydam & Weaver, 1975). Ma and Kishnor (1997) conducted a meta-analysis concerning the effect of mathematical self-concept and achievement in mathematics (ACH). They found a significant effect size of .23 (statistically different than zero) for self-concept about mathematics and ACH. The authors concluded that a positive self-concept about mathematics is associated with higher achievement in mathematics. Ma (1997) observed that attitudes towards mathematics (e.g., importance, difficulty, enjoyment) influenced achievement. As crucial as attitude towards mathematics is for mathematics achievement, understanding a student's academic related beliefs is also an important key to comprehending the achievement level (Dweck, & Elliot, 1983; Felson, 1984). Academic beliefs have been observed to impact the achievement level of students (Dweck & Elliot, 1983). Schoenfeld (1985) has pointed out that students' beliefs about mathematics may impede their ability to solve problems.

Extracurricular activities (EA) for students have been glorified and chastised over the years (Gerber, 1996). Two main of views of EA exist. The first view is that extracurricular activity is similar to a zero sum game where greater activity will subvert academic achievement (Coleman, 1961; Marsh, 1992). The second view is that EA experiences "further the total development of the students," thereby enhancing non-academic goals and possibly facilitating academic goals (Holland & Andre, 1987).

More specifically, part time employment, a common activity for American high school students, has shown to have a negative influence on achievement (e.g., Brown & Steinberg, 1991; Cooper et al., 1999), a positive influence (D'Amico, 1984), or no influence (Green & Jacquess, 1987). Cooper, et al. (1999), reported that number of hours per week was significantly negatively associated with a standardized test (-.29) and with teacher assigned grades (-.17). With 51.6% of high school senior female students and 47.5 percent of high school senior male students working, the examination of the effects of employment on achievement should continue (Green, Dugoni, Ingels, and Camburn, 1995).

Another common extracurricular activity is athletics (e.g., football, softball, baseball, soccer, track, and basketball). A review of research by Holland and Andre (1987) focused on the examination of the relationship between athletic participation and achievement. They reported that the research demonstrated that male high school athletes received somewhat higher grade-point averages (GPA's) than did non-athletes. When one considers standardized achievement or aptitude tests, males, whose only after school activity is sports, scored lower than national averages on the Standardized Achievement Test. No significant difference in either grade-point average or standardized test scores was observed between female athletes and non-athletes.

Another common after school activity associated with achievement is homework. Cooper (1989) observed a positive linear relationship between hours per week spent on homework (0 to 10 hrs) and achievement.

Television has traditionally been assumed to lessen achievement (Comstock, 1991, Keith et al., 1986). Simply, television viewing displaces academic activities and reduces the amount of time available for completing homework and other academic activities, thereby reducing achievement. Keith, et al., (1986) observed a small but negative relationship between the amount of television watched and achievement. In a review of research, Williams, Haertel, Haertel, and Walberg (1982) observed that the effect changes across the range of viewing times. The effect is very slightly positive up to ten hours per week and then becomes negative. The negative effect increases and is extreme after thirty hours per week. A more recent study by Cooper et al., (1999) observed a significant negative association between achievement and television viewing (mean viewing was 1-2 hours per night).

Differences in achievement for male and female students have been observed (More & Smith, 1987; Sherman, 1987; Anderson, 1989). Currently there is still debate about the observed differences. Some researchers have observed a large difference (Benbow & Stanley, 1980) and some no difference (Radhawa, Beamer, & Lundberg

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1993). The more consistent finding in the research appears to be that some differences still exist but not in all areas of mathematics (Fennema & Carpenter, 1981). Numerous research articles have been written concerning family background variables such as parental SES or parent education. (Keith & Cool, 1992; Lockheed and Komenan, 1989, McConeghy, 1987; Santiago and Okley, 1992). The positive relationship between parental socio-economic status (SES) or parent education level and achievement has been consistently observed (Heyns, 1978; Goleman, 1988). Similar results for SES have been observed in multilevel modeling (Lee & Bryk, 1989). The average school SES has been observed to be significantly related to mean school achievement in mathematics (the higher the school SES the higher the mean achievement) (Lee & Bryk, 1989; Raudenbush & Bryk, 1986).

Methodology

Sample

The sample for this study consists of the U.S. students from the Third International Mathematics and Science Study (TIMSS) Population 3 final year of secondary school cohort (High School Seniors) who were administered test booklets 3A, 3B, or 3C (Advanced Mathematics). All students who were administered the advanced mathematics instrument were designated advanced mathematics students or advanced mathematics and physics students. Total sample size is 2349 with 1158 females and 1191 males.

Analysis

To answer the research questions posed, a logistic regression analysis was conducted. The analysis was run in blocks. The first block contained background variables: Parent Education, Gender (Female), Math/Physics Expert. The second block contained the first block and affective factors: Attitude, Natural Talent, Hard Work. The final block included the previous two blocks and time variables: Television, Employment, Sports, Studying Math.

Variables

A listing of each variable, TIMSS label, and coding information is provided in Appendix A. The dichotomous outcome variable is based on the first plausible value of the advanced mathematics test. Students who scored over the international average, 501, were coded as one, and students who scored below the international average were coded as zero.

The independent variables are categorized into three areas:

Background of Student, which is composed of, Parent Education (dummy coded), Gender (Female), and Advanced Math/Physics;

After School Time, which is composed of, Television Viewing, Employment, Sports, and Studying Math;

Affective Factors, which is composed of Attitude, Natural Talent Belief, Hard Work Belief.

Results

Tables 1 and 2 provides descriptive statistics of the variables used. Table 3 provides results from the from the logistic regression analysis. Block 1 results indicate that parental education, gender (female) and advanced mathematics and physics were significantly related to scoring above international mean. Taking the exponential of the

Table 1 Frequency Tabulations of Dichotomous Variables

Variable	Count
Gender	
Male	1191
Female	1158

Advanced Math/Physics	
Advanced Math	1064
Advanced Math and Physics	1285
[1]Parent Education 1 (High School)	
No = 0	1298
Yes = 1	888
Parent Education (Elem. School)	
No = 0	2019
Yes = 1	167

1. Note: 1131 students had parents who graduated from a university, 888 from highschool, 167 only elementary school.

Table 2 Descriptive Statistics for Continuous Variables

	Mean	sd	Min.	Max.
Attitude	10.09	2.91	5	20
Natural Talent	2.40	0.76	1	4
Hard Work	1.66	0.70	1	4
Television	2.71	0.96	1	5
Employment	2.54	1.64	1	5
Sports	2.34	1.19	1	5
Studying Math	2.17	0.78	1	5

coefficient for advanced mathematics and physics (e^1.105) provides an odds ratio of 3.019 which indicates that students enrolled in advanced mathematics *and* physics were three times as likely to score above the international average than students only enrolled in advanced mathematics. Students whose parents had only completed elementary school (e^-1.368) were only one-fourth as likely to score above the international mean. The Hosmer and Lemeshow statistic indicates that the model was a good fit. The Cox and Snell and Nagelkerke R-Square values indicate less than 20 percent of the "variance" was accounted with the Block 1 variables. These values are analogous to the traditional R-Square in multiple regression, but are specific to logistic regression due to the dichotomous dependent variable.

The results from the Block 2 analysis indicate that all the variables, except Gender, were significantly related to scoring above the international mean. This indicated the possibility of an interaction between female and the affective variables. Since the interaction of affective variables and gender are well documented (McLeod, 1992), intermediate models were run (Table 4) to examine the association of interactions on the

Table 3: Logistic Regression Results for the Three Blocks

Factor	Block1		Block2		Block 3	
	Beta	se	Beta	se	Beta	se
High School	-1.172	0.17	-1.313	0.12	-1.252	0.12
Elem. School	-1.368	0.25	-1.699	0.28	-1.756	0.28
Gender (Female)	-0.375	0.10	-0.209	0.11	-0.392	0.12
Advanced Math & Physics	1.105	0.11	0.976	0.12	0.913	0.12
Attitude			-0.266	0.02	-0.256	0.02
Natural Talent			-0.455	0.08	-0.457	0.08
Hard Work			0.392	0.08	0.499	0.08
TV					-0.166	0.06
Job					-0.172	0.05
Sports					-0.163	0.04
Math Study					0.272	0.08
-2log	2260.85		2007.13		1938.44	
Hosmer-Lemeshow X2	5.823 df=6		8.66 df=8		5.968 df=8	
Cox & Snell R^2	.126		.214		.231	
Nagelkerke R^2	.183		.309		.335	

model (Gender*Attitude, Gender*HardWork, Gender*Natural Talent). The interactions were not significant, the –2log did not significantly change, and the R-Square estimates were not significantly altered. According to Hosmer and Lemeshow (1989) this indicates that affect may be a confounder but not an effect mediator.

Table 4 Examination of Gender and Affect Interaction

	B	Se	-2Log	Cox and Snell R^2	Nagelkerke R^2
Gender*Attitude	0.03	0.04	2006.66	.214	.310
Gender*Natural Talent	-0.17	0.15	2005.79	.214	.310
Gender* Hard Work	-0.18	0.16	2005.82	.214	.310

Also, after including affect variables –in essence statistically controlling for the association of affect- changes in the negative association of formal parent education changes were evident. The coefficients for both variables increased. The impact of being enrolled in advanced mathematics and physics had a decrease in association from Block 1 to Block 2. For the continuous variable Attitude, the results indicate the worse the students attitude the less likely the student scored over the international average. The coefficient for Natural Talent indicates that the more a student believed that natural talent was a key to mathematics success the more likely the student scored above the international average. Finally, the less a student believed in hard work as a key to mathematics success the more likely the student scored over the international average.

The –2 log value dropped from Block 1 to Block 2 and the Hosmer Lemeshow statistic indicates that the Block 2 model is a good fit for the data. Finally, The R-square estimates indicate more "variance" was accounted for by the inclusion of the affect variables which was expected.

Block 3 results indicate that the variables from Blocks 1 and 2 and the new variables are significantly associated with scoring above the international mean. Taking the exponential of the Studying Math coefficient (e^.272) shows that for every one unit increase on the scale the student is 1.3 times more likely to score above the international average. For every one unit increase in work the students eight tenths as likely to score above the international mean.

From Block 2 to Block 3 the variable Gender went from not significant to significant indicating a possible interaction with extracurricular activities. Therefore, these interactions (Gender*Television, Gender*Employment, Gender*Sports, Gender*Studying Math) were examined. None of the interactions were significant and including the interactions did not significantly change the –2log or the R-Square values (Table 5).

Table 5 Interaction Effects of Gender by Extracurricular Activity

	B	se	-2Log	Cox and Snell R^2	Nagelkerke R^2
Gender*Television	0.002	0.112	1938.44	0.231	0.335
Gender*Job	0.050	0.073	1937.97	0.233	0.331
Gender*Sports	0.223	0.336	1937.32	0.232	0.336
Gender*Studying	0.028	0.154	1938.41	0.231	0.335

Though mostly completed with epidemiological research, a probability equation can be developed to examine a student's probability of scoring above the international average. The equation is:

$\pi(x) = \exp(A)/[1+\exp(A)]$, where

$A = 2.483 - 1.252(HS) - 1.756(ES) - .392(Fem) + .913(AMP) - .256(Att) - .457(NT) + .499(HW) - .166(TV) - .163(Sports) - .172(Job) + .272(MStdy)$.

A male student whose parents graduated from college, is not enrolled in advanced mathematics and physics, has a good attitude towards mathematics and average score on beliefs, watches TV, works, plays sports and studies a couple of hours per day, would have a value of 0.48 indicating a 48 percent probability of scoring above the international average. Keeping everything the same except making the student enrolled in both advanced mathematics and physics increases the value to .74. Using an equation such as this is only useful when the variables can be controlled, such as working and studying.

Discussion/Conclusions

With the publication of the international scores and the discussion about the rank of American students average score it was important to look at factors that were associated with scoring above the international mean. The advanced mathematics and advanced mathematics and physics students were chosen because there has been less emphasis on their performance. Using such a unique group of students it was hoped by

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the author that traditional variables would not have a strong impact on scoring above or below the international average. Unfortunately, formal parent education level and gender were significantly associated with scoring above the international mean showing that this traditionally observed disparity still exists. This indicates that there is still a great deal of work to be done to close this gap. The results indicate a more in-depth examination of this is needed. For example, a case study of two classroom of advanced mathematics students followed for a year in an attempt to understand why the disparity exists.

The result for advanced mathematics and physics students was expected. Students who are concurrently enrolled in mathematics and physics courses see many of the same equations and solve many of the same types of problems. The dual coverage of content, amount of time with the material, similar activities in the courses, provides the students more opportunity to learn the content. Therefore, advanced mathematics and physics students are potentially spending twice as much time during each day with advanced mathematics problems. Another aspect that may be influencing the difference is an abstract to concrete representation of the material (Danesi, 1993). A great deal of work completed in advanced mathematics courses may appear to students to be abstract. In the physics course those students may be seeing concrete representations of the abstract ideas from their mathematics course. The connection may have assisted the students who are enrolled in both course score above the international average. But this too needs to be researched further to examine if this could be contributing to the observed difference or something else, such as students who are concurrently enrolled in both courses have more "ability" or a higher "IQ."

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The affective factors, though important to understand and monitor are difficult to change. Being a former mathematics instructor, the author understands the difficulty in attempting to change attitudes and beliefs that have developed over many years. More importantly, though, the results demonstrate that our most advanced students are impacted in a similar way as the rest of our mathematics students (Schreiber, 2000). Affective factors are associated with student performance and need to be considered.

Time variables, overall, may be more readily modified than affective factors. Their association is smaller in the model than other variables, but still significant. As students engage in more hours per day in these activities they may positively (studying) or negatively (TV, job, sports) impact performance. Scoring above the international average in this study is associated with less time in non-academic activities and more time studying. The issue is not to remove these activities because they do provide a great deal of societally beneficial effects (time management, responsibility, working as a group, school retention), but to monitor the amount of time and energy these activities are absorbing. Even within these observations, more in-depth research needs to be conducted on the effects of different types of activities (e.g., school/non school, academic/non-academic, organized/unorganized) on achievement.

The most disturbing finding from the study may not be from the model. The disturbing part is only twenty six percent of our most advanced students scored above the international mean. It does appear that our most advanced mathematics students are not reaching the level we expect, and that many of the traditional variables are still associated with the scores.

Finally, this study is from a very select group of students and is only one model or view of the factors associated with mathematics achievement. Therefore, the reader is reminded that these results should be weighed with previous observations and other research findings.

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Appendix A

The following variables were either selected from those in the TIMSS Population 3 data set or were developed using other variables from the data set.

1. Gender: ITSEX 1 = Female 0 = Male
2. Parent Education: CSDGEDU. This variable was dummy coded into:

	Parent Education 1	Parent Education 2
University Graduate	0	0
High School Graduate	1	0
Primary School Graduate	0	1

3. Advanced Math/Physics: IDSUBPOP Recoded 1= Adv. Math and Physics, 0 = Advanced Math
4. Attitude (Composite): CSBENJY, CSBMBORE, CSBMEASY, CSBMLIFE, CSBMLIKE. For each individual variable 1 = strongly agree 4 = strongly disagree. CSBMBORE and CSBMLIKE were reverse coded to match the direction of the others. The variables were added together to create the composite. The lower the attitude score the better the attitude towards mathematics in general. Alpha = .8241
5. Natural Talent: CSBMDOW1 1= strongly agree 4= strongly disagree. Those who chose strongly agree indicated that natural talent was the key to mathematics success.
6. Hard Work: CSBMDOW3 1= strongly agree, 4= strongly disagree. Those who chose strongly agree indicated that hard work was the key to mathematics success.
7. Television: CSBGDAY1 1= No time per school day, 2=Less than one hour per school day, 3= 1-2 hours per school day, 4= 3-5 hours per school day, 5 = more than five hours per school day.
8. Sports: CSBGDAY6 1= No time per school day, 2=Less than one hour per school day, 3= 1-2 hours per school day, 4= 3-5 hours per school day, 5 = more than five hours per school day.
9. Employment CSBGDAY5 1= No time per school day, 2=Less than one hour per school day, 3= 1-2 hours per school day, 4= 3-5 hours per school day, 5 = more than five hours per school day.
10. Studying Math: CSBGDAY 8 1= No time per school day, 2=Less than one hour per school day, 3= 1-2 hours per school day, 4= 3-5 hours per school day, 5 = more than five hours per school day.
11. Television: CSBGDAY1 1= No time per school day, 2=Less than one hour per school day, 3= 1-2 hours per school day, 4= 3-5 hours per school day, 5 = more than five hours per school day.

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Printed Name/Position/Title: James B. Schreiber ASST. PROF

Organization/Address: SIU-C, ED. PSYCH & SPECIAL ED MAIL CODE 4618 Carbondale, IL 62901

Telephone: 618 453 2524

FAX: 618 453 7110

E-Mail Address: jschreib@siu.edu

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